Underground Exposures for Hydroelectric Plants
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Hydroelectric Schemes

Working Group Members:

Chairman: Tim Chapman SCOR

Contributors: Tom Wylie
Carolina Puerta AXA XL
Thomas Raetzo SwissRe
Andrea Belli Swiss RE

IMIA EC Sponsor: Stephan Lammle, MuRe
Hydroelectric Schemes

Hydro projects are very complex comprising a number of items including:

- Dam
- Diversion tunnels,
- Cofferdams,
- Headrace tunnel
- Surge tank,
- Penstock,
- Power house
- Tail race tunnel.
- Generator and turbines.
- Access roads

This paper focuses on the underground exposures.

With a focus on market losses to determine the main damaged element

https://science.howstuffworks.com/environmental/energy/hydropower-plant1.htm
Review Process

- Review Notable Market Losses
- Review Portfolio of circa 30 hydro Losses
- Determine Predominant damage
- Engage with Loss adjusters, Risk Control Eng’s & specialist geotechnical Eng’s
## Notable Losses

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Location</th>
<th>Project Type</th>
<th>Damage</th>
<th>Date of Loss</th>
<th>Quantum / digit figure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reventazon Hydroelectric Project</td>
<td>Costa Rica</td>
<td>HPP</td>
<td>i) Spillway</td>
<td>2018</td>
<td>Low</td>
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<td></td>
<td></td>
<td></td>
<td>ii) Turbine</td>
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<tr>
<td>Ituango</td>
<td>Columbia</td>
<td>HPP</td>
<td>Diversion tunnel</td>
<td>2018</td>
<td>High</td>
</tr>
<tr>
<td>Laos Dam</td>
<td>Laos</td>
<td>Saddle Dam linked to HPP</td>
<td>Dam collapse</td>
<td>2018</td>
<td>High</td>
</tr>
<tr>
<td>Jirau</td>
<td>Brazil</td>
<td>HPP</td>
<td>Riots and building fire</td>
<td>2011</td>
<td>High</td>
</tr>
</tbody>
</table>
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</tr>
</thead>
<tbody>
<tr>
<td>Chaglla Hydro</td>
<td>Peru</td>
<td>HPP</td>
<td>Tunnel collapse and ground failure</td>
<td>2016</td>
<td>Low</td>
</tr>
<tr>
<td>Shuakhevi (Georgia Hydro)</td>
<td>Georgia</td>
<td>HPP</td>
<td>Multiple tunnel collapses</td>
<td>TBA</td>
<td>Med</td>
</tr>
<tr>
<td>Alto Maipo (AES)</td>
<td>Chile</td>
<td>HPP</td>
<td>Multiple rock bursts in the tunnel</td>
<td>2018</td>
<td>Low</td>
</tr>
<tr>
<td>Glendoe</td>
<td>UK - Scotland</td>
<td>HPP</td>
<td>Tunnel collapse</td>
<td>2009</td>
<td>Med</td>
</tr>
</tbody>
</table>
Notable Losses

A review of the notable losses identifies that:

- The majority of the losses occurred during construction. The two exceptions being:
  - Reventazon HPP – damage to the spillway
  - Glendoe – in maintenance period

- The majority of losses related to tunnel damage. The exceptions being:
  - Reventazon – turbine over speeding and spillway damage
  - Laos – dam failure
  - Jirau – riots and building fire
Loss Analysis

• We have also reviewed a wider range of hydroelectric claims by region, occupancy and whether above or below ground.
• Include damage to a variety of HPP structures including the dam itself, bridges, CPE, turbines and the construction sites
• Variety of causes including flood, landslide, lightening.
• The results of this are summarized as follows:
Causation

- Note however that there has been significant HPP development in Latin America.
- Consequently there have been a significant number of projects in this region
Causation
Causation

Damage Above or Below Ground

- Above Ground: 5%
- Under Ground: 95%

Under Ground  
Above Ground
Causation

Earthquake Zone

Earthquake Location

- Reventazon, Costa Rica is in Zone 4 earthquake
- Ituango, Columbia is in Zone 4 earthquake
- Chaglla, Peru is in Zone 3 earthquake
- Alto Maipo, Chile is in Zone 4 earthquake
In conjunction with our review of claims and discussions with loss adjusters, geotechnical engineers and risk control engineers involved with investigating HPP losses we identified common themes:

- HPP tend to be constructed in mountainous regions that can subject to complex and disturbed geology.

- Tunnelling in volcanic rock has specific issues
  - Zeolite is found in minerals and includes laumonlite and waikarite which can damage the shotcrete.
  - Clay minerals can cause risk swelling and additionally they can degrade over time when exposed to air and water. Geologists are not always checking for the presence of these.

- Some geological faults contain gypsum which dissolves over time and can lead to instability of the surrounding ground and / or lining.

- Geological faults are not always identified by the SI and additionally can be missed by the site geotechnical engineer carrying out the face mapping.
Causation

• Risk assessments should consider geology and mineralogy and this is not always being done.
• There is an increase in the use of unlined or partially lined tunnels. Older HPP schemes tended to use steel or concrete linings that would separate the water from the rock. There have been cases of the partial lining being undermined and subsequently failing.
• It is recommended to form an invert to prevent erosion by debris from undermining the sides of the tunnel.
• There are particular features that are specific to HPP tunnels
  o It is difficult to carry out a thorough SI because of significant overburden and access restraints at ground level.
  o They can be subject to high internal pressures due to the high head of water. Equally when drained there will be no internal pressure but there could be significant build up of pressure behind the lining.
Future Underwriting Considerations

• The paper makes reference to:
  • Insurance Cover
  • Underwriting Considerations

• Significant items to consider are:
  • How detailed is the SI, is an interpretative SI provided. What are the recommendations?
  • The geotechnical conditions – fault / shear zone locations. How are these being dealt with?
  • What is the process for ongoing face mapping
  • What form of lining is being used – lined, partially lined, unlined.
Future Works

• As a joint initiative with LEG we attended a presentation at the BTS where we discussed the issues relating to tunnel collapse with the Chairwoman. They confirmed that they would consider providing us a slot at one of their evening meetings.

• Good opportunity to work jointly with LEG / ICEIG to consider the next steps for HPP tunnels.
Dam Structures

Bulletin 99 - Dam Failures, Statistical Analysis - International Commission of Large Dams (ICOLD) reviewed the cause of incidents to dams on a world wide basis. Data from over 180 dam incidents some under construction. References three specific cases which suffered from instability and sliding earthfill of the dam itself.

Some of the key findings of this paper include:

• Most failures are to newly built dams
• For concrete dams the most common cause of failure is foundation problems relating to internal erosion and insufficient shear strength
• For earth and rockfill the most common cause of failure is i) overtopping ii) internal arosion
• For masonry the most common cause is i) overtopping ii) internal erosion
• Other notable causation was inadequate spillway capacity.